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Mechanical properties and corrosion resistance of some titanium alloys in marine environment

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Abstract. Titanium alloys are used in several fields such as aerospace industry or biomedical. They are increasingly used in marine applications, a highly corrosive environment. We chose titanium alloys for their good properties such as high mechanical strength, low density and excellent corrosion resistance. This study is focused on titanium alloys potentially interesting to be used in marine transports, and mainly for the boats fittings such as a winch for example.

INTRODUCTION

The marine environment exposes the materials to conditions which can generate their degrading. Several modes of degrading exist such as sea air, seawater, and bacteria. It is necessary to evaluate the materials resistance to corrosion and to determine ways to protect them against degradations created by this environment.

In this study, we chose to study titanium alloys for their good mechanical properties, low density and excellent corrosion resistance. First, metallurgical and mechanical characterizations have been done. Then, corrosion tests have been done with a three-electrodes setting in three different electrolytes. Measurements selected are corrosion potential and current density according to the potential value applied. We are trying to define experimental Tafel parameters.

In order to optimize the mechanicals properties, thermal treatments have been done. On the other hand, surface treatments have been also done to increase the corrosion resistance of the materials in marine environment. Corrosion tests have been done on different titanium alloys with or not surface treatments in three electrolytes (3 pH values 1.33_7.68_12.22).

Information in this study is needed to select the alloy which is most resistant to environmental and mechanical stress. The tests allow us to choose the most appropriate material for our marine applications with a specific surface treatment.

EXPERIMENTAL TECHNIQUES AND MATERIALS

Before characterizing alloys, heat treatments have been done (solution heat treatment followed by quenching, cold-rolling process, recrystallization and aging treatment) [1, 2]. Characterizations have been done for the recrystallized and aged materials.

Microstructure observations were carried out by using an optical microscope and a scanning electron microscopy (CMEBA system). Samples were first polished and then etched with a hydrous solution consisting of 2.5% HF, 2.5% HNO_3 and 95% H_2O. X-ray diffractions were performed with a Philips generator system (copper $K\alpha_1$ radiation). Mechanical characteristics have been determined by tensile tests (INSTRON 3369 with a deformation rate of $10^{-4}\ s^{-1}$) and by Vickers microhardness measurements.

The device used for corrosion tests was a three-electrodes setting (VoltaLab PGZ100) [3–5]. An artificial seawater was used to simulate the marine environment and to compare the results obtained in different electrolytes.

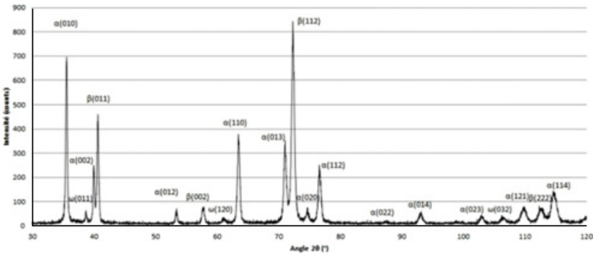

Figure 1. X-ray diffractogram for Ti-6.8 Mo-4.5 Fe-1.5 Al, after aging treatment.

EXPERIMENTAL RESULTS

The following experimental results are obtained for a metastable β titanium alloy, Ti-6.8 Mo-4.5 Fe-1.5 Al.

a) Microstructure

Figure 1 shows an X-rays diffractogram for Ti-6.8 Mo-4.5 Fe-1.5 Al.

The peaks observed belong to α and β phase of titanium and show that Ti-6.8 Mo-4.5 Fe-1.5 Al is an α/β phases mixing. β phase is stable at high temperature and α phase is stable at low temperature. The molybdenum and iron alloying elements are classified as β-stabilizers, they stabilize the β phase field to room temperature. Some minority peaks showing the ω phase presence in the alloy

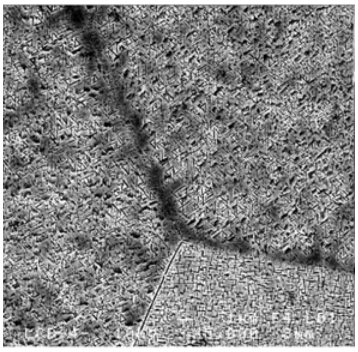

Figure 2. Microstructure of Ti-6.8 Mo-4.5 Fe-1.5 Al observed with a SEM.

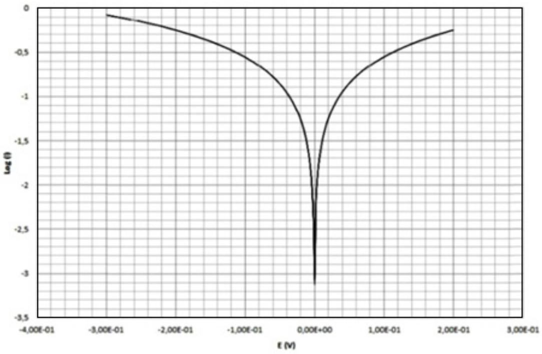

Figure 3. Ti-6.8 Mo-4.5 Fe-1.5 Al Tafel curve in NaCl 3% electrolyte.

can be observed. This phase appeared during the slow cooling following the aging.

Lattice parameters obtained for this diffractogram are the following:

α phase (hexagonal close packed): a = 2.94 Å et c = 4.68 Å

β phase (body-centered cubic): a = 3.2085 Å

Microstructure (SEM observations) is shown in Figure 2:

β grains triple joint (with α phase fine lamellae) can be observed.

b) Mechanicals properties

For Ti-6.8 Mo-4.5 Fe-1.5 Al, following results after heat treatment, are:

- Vickers microhardness: 450 $HV_{0,3}$ (average with 20 measures).
- Tensile strength: 1400 MPa.

c) Corrosion tests

Ti-6.8 Mo-4.5 Fe-1.5 Al Tafel curve is shown in figure 3.

Following parameters are graphically determined:

- Corrosion potential: $E_{corr} = 0$ V
- Current density: $J_0 = 1.38 \times 10^{-5}$ $A.m^{-2}$
- Anodic Tafel parameter: $\beta_a = -0.299$ V
- Cathodic Tafel parameter: $\beta_c = 0.294$ V

CONCLUSION

Ti-6.8 Mo-4.5 Fe-1.5 Al characterizations give good results. This alloy study will go further with corrosion characterization on surface treated samples. Others titanium alloys will be also studied.

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